

I/U curve tracer

driven via the PC printer port

Source: Maxim Integrated Products

With a set of Maxim A/D and D/A converters and a handful of other components, you can make a curve tracer that can be driven from the printer port of a PC. A simple BASIC program takes care of the communication between the PC and the measurement circuit, and also converts the measured values into graphic form for display on the monitor.

Not long ago, it was common practice to measure the I/U characteristics of a semiconductor device using an X-Y oscilloscope and a suitable measuring circuit. An electronics engineer can extract a lot of information about the operation of the semiconductor from these curves.

In the present computer age, the I/U curve may well have dropped into obscurity, but it is still useful for evaluating a number of specific semiconductor characteristics. The only difference is that we no longer need an oscilloscope, since we can instead employ the versatile PC.

With the measurement circuit presented here, which comes from Maxim, the I/U characteristics of a semiconductor or IC can be measured and then displayed on the monitor. This is made possible by the use of two serial-interface ICs: a 12-bit DAC and a 12-bit ADC. A short BASIC program looks after controlling the circuit and displaying the data on the screen. Since the circuit is designed for use with a standard PC printer port, the interaction between the circuit and the computer is very simple.

The hardware

Figure 1 shows the schematic diagram of the hardware. IC4 is a 12-bit D/A converter that is configured for a bipolar output voltage with a range of plus and minus 2.048 V. The opamp IC6a, which is connected to the V_{out} pin, amplifies this voltage by a factor of 2, so that a voltage ranging between plus and minus 4.096 V is present at the output of IC6a. IC7 in turn converts this voltage into a current that is proportional to the voltage. This is the

test current for the device being measured.

The current ranges from $\pm 40 \mu A$ to $\pm 40 mA$, depending on the value selected for the resistance of R_{SENSE} (100 Ω , 1 k Ω , 10 k Ω or 100 k Ω). The

maximum output current is approximately equal to the value of the output voltage of IC6a (4.096 V) divided by the value of R_{SENSE} .

The current through the DUT (device under test) produces a voltage drop

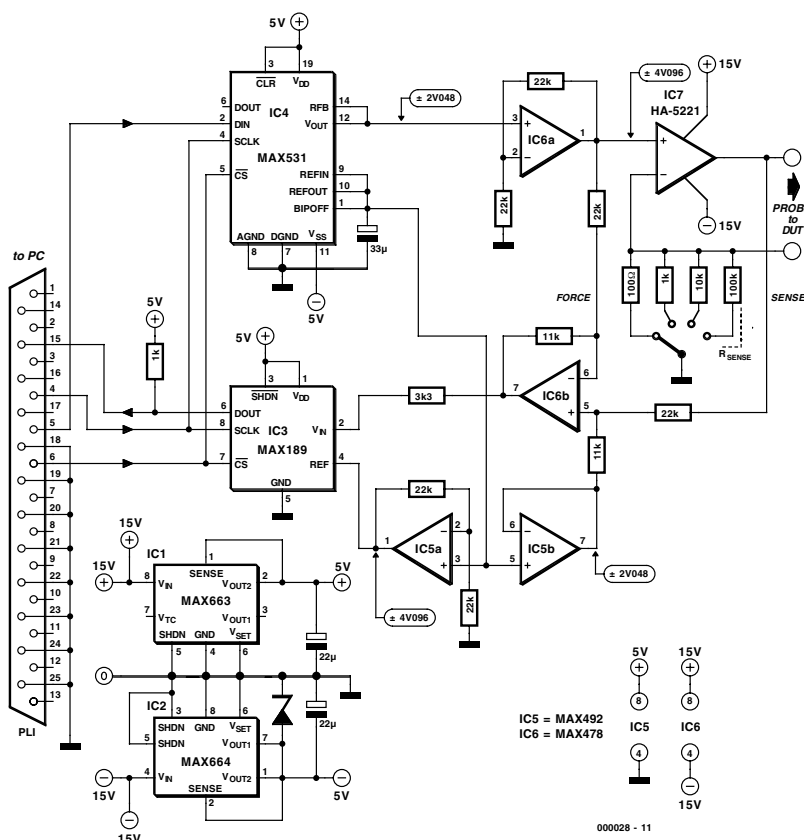


Figure 1. The main components of the circuit are a set of Maxim serial-interface A/D and D/A converters.

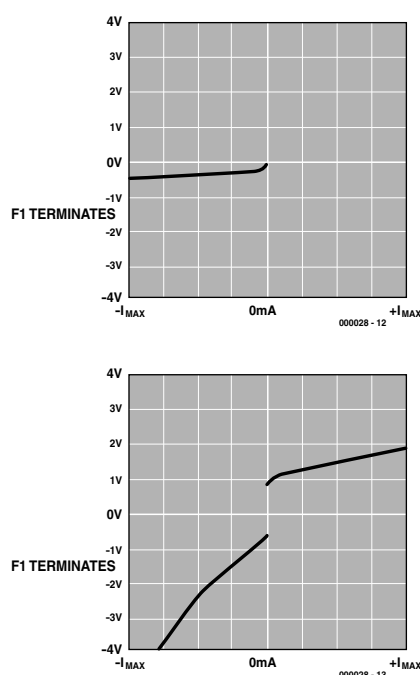


Figure 2. Two examples of measured I/U curves: (a) shows a Schottky diode, while (b) shows a more complex analogue IC.

across the component. This voltage is measured by the difference amplifier IC6b. In order to avoid an offset error that depends on the value of the selected current-sensing resistor, the signal for the inverting input of this opamp is taken from the low-impedance non-inverting input of IC7. The disadvantage of this is a fixed error equal to the input offset of IC7.

The amplification of the difference amplifier, in combination with the added offset, yields a maximum output swing of 0 to 4.096 V. This is exactly the right range for the unipolar input of the 12-bit A/D converter (IC3). The 3.3-k Ω resistor in series with the input of the ADC limits the input current in case the output voltage of IC6b should be greater than the supply voltage of IC3.

When a measurement is being made, the software drives the DAC such that it produces a 'staircase' current. The resulting voltage across the DUT is measured by the ADC and then displayed on the PC monitor, with a resolution of 640 x 480 pixels. The two examples shown in **Figure 2** illustrate some typical results. A resolution of 12 bits is actually somewhat luxurious for this applica-

```
'LISTING 1 - BASIC PROGRAM

'LPT1 OUT @ &H378, IN @ &H379
'LPT2 OUT @ &H278, IN @ &H279

'25 WAY D TYPE

'SIGNALS TO CIRCUIT
'PIN 4 D2 (OUT) SCLK
'PIN 5 D3 (OUT) DATA OUT (FROM PC)
'PIN 6 D4 (OUT) CS\

'SIGNALS FROM CIRCUIT
'PIN 15 D3 (IN) DATA IN (TO PC). ALSO SIGNALS EOC
'PINS 18-25 ARE GROUND

'INTRODUCTION

PRINT "WELCOME TO THE MAXIM CURRENT-VOLTAGE CURVE TRACER"
PRINT

INTRO:
PRINT "WHERE IS THE CIRCUIT CONNECTED? ENTER 1 FOR LPT1 OR 2 FOR LPT2"
INPUT P%
IF P% = 1 THEN PORT% = &H378
IF P% = 2 THEN PORT% = &H278
IF P% = 1 OR P% = 2 THEN GOTO INTRO1
PRINT "WRONG!!!!!! PLEASE TRY AGAIN"
GOTO INTRO
INTRO1:

ON KEY(1) GOSUB FINISH
KEY(1) ON

MAIN:

'DEFINE SOME VARIABLES
DIM Y(512)
DIM DIN(12) AS INTEGER, DOUT(12) AS INTEGER

'SET UP DISPLAY FOR OUTPUT
CLS 0
SCREEN 12
WINDOW (-120, -55)-(520, 435)
LINE (0, -5)-(0, 410), 1
LINE (-5, 0)-(512, 0), 1
LINE (512, -5)-(512, 410), 1
LINE (-5, 410)-(512, 410), 1
LINE (-5, 205)-(512, 205), 1
LINE (256, -5)-(256, 410), 1
LINE (-5, 51)-(0, 51), 1
LINE (-5, 102)-(0, 102), 1
LINE (-5, 153)-(0, 153), 1
LINE (-5, 256)-(0, 256), 1
LINE (-5, 308)-(0, 308), 1
LINE (-5, 359)-(0, 359), 1
LINE (64, -5)-(64, 0), 1
LINE (128, -5)-(128, 0), 1
LINE (192, -5)-(192, 0), 1
LINE (320, -5)-(320, 0), 1
LINE (384, -5)-(384, 0), 1
LINE (448, -5)-(448, 0), 1

COLOR 9
LOCATE 1, 1, 0: PRINT "MAXIM CURRENT-VOLTAGE CURVE TRACER"
LOCATE 20, 1, 0: PRINT "F1 TERMINATES"
LOCATE 2, 12, 0: PRINT "+4V"
LOCATE 15, 13, 0: PRINT "0V"
LOCATE 27, 12, 0: PRINT "-4V"
LOCATE 28, 15, 0: PRINT "-Imax"
LOCATE 28, 46, 0: PRINT "0mA"
LOCATE 28, 75, 0: PRINT "+Imax"

LOCATE 10, 1, 0
PRINT "Rs Imax"
PRINT "100R 40mA"
PRINT "1K 4mA"
PRINT "10K 400uA"
PRINT "100K 40uA"

START:
IDATA% = &H10
OUT PORT%, IDATA%

Z% = 8

'F1 EXISTS
'MAIN BIT OF PROGRAM
'ARRAY TO HOLD PLOT DATA
'DATA IN AND DATA OUT
'VGA SCREEN
'DEFINE WINDOW CO-ORDINATES
'DRAW A FEW LINES
'CENTRAL AXES
'MARKERS
'LABELS
'START OF PLOT ROUTINE
'INITIALISE PORT, SCLK=0, CS\=1
'INITIALISE MAX531
```

GOSUB IO

```
FOR X& = 1 TO 511 STEP 1
  Z& = 8 * (X& + 1)
  GOSUB IO
```

```
PSET (X&, Y(X&)), 0
IF Y(X&) = 0 THEN PSET (X&, Y(X&)), 1
IF Y(X&) = 205 THEN PSET (X&, Y(X&)), 1
IF X& = 256 THEN PSET (X&, Y(X&)), 1
Y(X&) = INT(ODATA& / 10)
IF Y(X&) > 408 THEN Y(X&) = 409
IF Y(X&) < 1 THEN Y(X&) = 1
PSET (X&, Y(X&)), 4
NEXT X&
GOTO START
```

```
IO:
ODATA& = &H0
IDATA& = IDATA& AND &HEF
OUT PORT&, IDATA&
WAIT (PORT& + &H1), &H8
```

```
IDATA& = IDATA& OR &H4
OUT PORT&, IDATA&
IDATA& = IDATA& AND &HF3
OUT PORT&, IDATA&
```

```
FOR SHIFT = 11 TO 0 STEP -1
  DOUT(SHIFT) = (INP(PORT& + &H1) AND &H8)
  ODATA& = ODATA& + DOUT(SHIFT) * 2 ^ (SHIFT - 3)
  IDATA& = IDATA& OR ((Z& AND (2 ^ SHIFT)) / (2 ^ SHIFT) * 8)
```

```
OUT PORT&, IDATA&
IDATA& = IDATA& OR &H4
OUT PORT&, IDATA&
IDATA& = IDATA& AND &HF3
OUT PORT&, IDATA&
NEXT SHIFT
```

```
IDATA& = IDATA& OR &H10
OUT PORT&, IDATA&
```

```
RETURN
FINISH:
END
```

```
'X& IS X AXIS FOR PLOT
'NEXT VALUE FOR MAX531
```

```
'RESET BACKGROUND
'CATCH BOTTOM LINE AT START
'CATCH HORIZ CENTRE LINE
'CATCH VERT CENTRE LINE
```

```
'CHECK FOR OVER-RANGES
```

```
'SET NEW VALUE
```

```
'AROUND AGAIN
```

```
'DATA I/O ROUTINE
```

```
'CS\ SET TO 0
```

```
'WAIT FOR EOC FROM CIRCUIT
```

```
'SCLK CYCLE TO SHIFT 189 DATA TO DOUT
'SCLK TO 1
```

```
'SCLK TO 0
```

```
'GET DATA FROM MAX189
'COMPILE DATA
'DATA TO GO TO MAX531
```

```
'SCLK TO 1
```

```
'DATA BIT BACK TO 0, SCLK TO
```

```
'CS\ SET TO 1
```

tion, but the software can be modified to work with higher resolutions, and you could even add a loop to the software for this.

Now we come to a few practical remarks regarding the power supply. IC7 and IC6 need a symmetrical supply voltage of ± 15 V in order to operate over the desired range. All other ICs need only a ± 5 V supply. The voltage regulators MAX663 and MAX664 (IC1 and IC2) provide the necessary voltages.

The QBASIC program shown in the accompanying listing starts by asking which printer port the circuit is connected to (1 or 2). After this, the graphic plot of the I/U curve of the device being tested appears on the screen. You can exit the program by pressing the function key F1. Make sure to run the program in true DOS mode, rather than in a DOS box under Windows. QBASIC can usually be found in a folder labelled 'OLDMSDOS' on the Windows CD, or else you should use an old version of MS-DOS.

(000028-1)

The BASIC program 'I-V Curve Tracer' was written by Terry Millward of Maxim UK, and is available at the Maxim web site:

www.maxim-ic.com/TechSupport/other.htm

Serial-interface converters

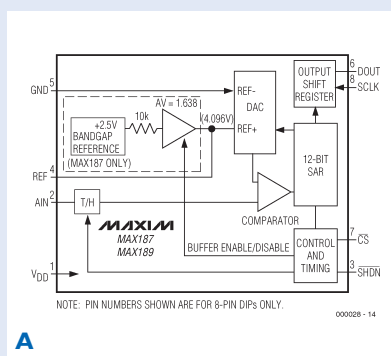
The simplicity of the circuit described in this article is primarily due to the use of a set of serial-interface converters, namely the MAX 189 and MAX 1531. The MAX 189 is a serial A/D converter with a resolution of 12 bits that works with a single +5 V supply. Its input voltage range also lies between 0 and +5 V. The core of this IC is a successive-approximation ADC with a conversion time of 8.5 μ s. This is complemented by a fast sample and hold circuit (1.5 μ s), an on-chip clock generator and a fast serial three-wire interface (see the block diagram in **Figure A**).

The conversion rate of the MAX 189 is 25 kilo-samples/s. Thanks to its built-in interface, this IC can be easily connected to a PC or microprocessor, as can be seen in this application. In contrast to its companion MAX 187, the MAX 189 does not have an internal reference, but this is not necessary in this application since the DAC that is used provides the reference voltage. The very low operating power consumption (7.5 mW) makes this IC very suitable for battery-powered applications. In the shutdown mode, the power consumption drops to only 10 μ W.

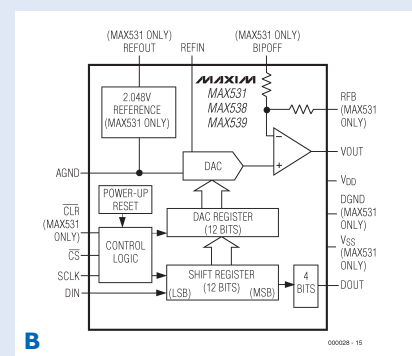
The MAX 189 is available in an 8-pin DIP package and a 16-pin SOI package.

The MAX 1531 can be seen as a complement to the MAX 189. Its block diagram is shown in **Figure B**. This 12-bit D/A converter also works with a single +5 V supply. The MAX 1531 was specifically chosen for this application, which requires a bipolar output voltage, since it can also work with a symmetrical ± 5 V supply. The current consumption of the MAX 1531 is only 260 μ A, including the internal 2.048 V reference source. The IC is housed in a 16-pin DIP or SOI package. The offset voltage, amplification and linearity are adjusted during manufacturing, so the user does not have to be concerned with them.

The internal output opamp of the MAX 1531 can be configured for an amplification factor of 1 or 2, and for a unipolar or bipolar output voltage. An internal shift register stores the serial data supplied to the IC.



A



B